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Lange

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(54) **DETERMINING A SET OF ACCESS POINTS IN RESPONSE TO A GEO-LOCATION REQUEST**

(58) **Field of Classification Search**
CPC H04W 64/00; H04W 4/023; H04W 64/003
USPC 455/456.2, 453, 404.2, 456.1
See application file for complete search history.

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This patent is subject to a terminal disclaimer.

(Continued)

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(74) *Attorney, Agent, or Firm* — Ryan, Mason & Lewis, LLP

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(57) **ABSTRACT**

Related U.S. Application Data

Methods, apparatus, and processor-readable storage media for determining a set of access points in response to a geo-location request are provided herein. An example computer-implemented method includes determining, based on geo-location information comprising a set of at least two coordinates attributed to at least one device, geo-location information attributed to a set of multiple access points; identifying two or more access point sub-sets from the set of access points, wherein each of the access point sub-sets comprises one or more of the access points; comparing geo-location information attributed to additional devices to the access points within each of the sub-sets; and outputting, to the at least one device as a response to a request for geo-location information comprising a set of at least two coordinates and based on said comparing, information pertaining to at least one of the sub-sets and the geo-location information attributed to the at least one device.

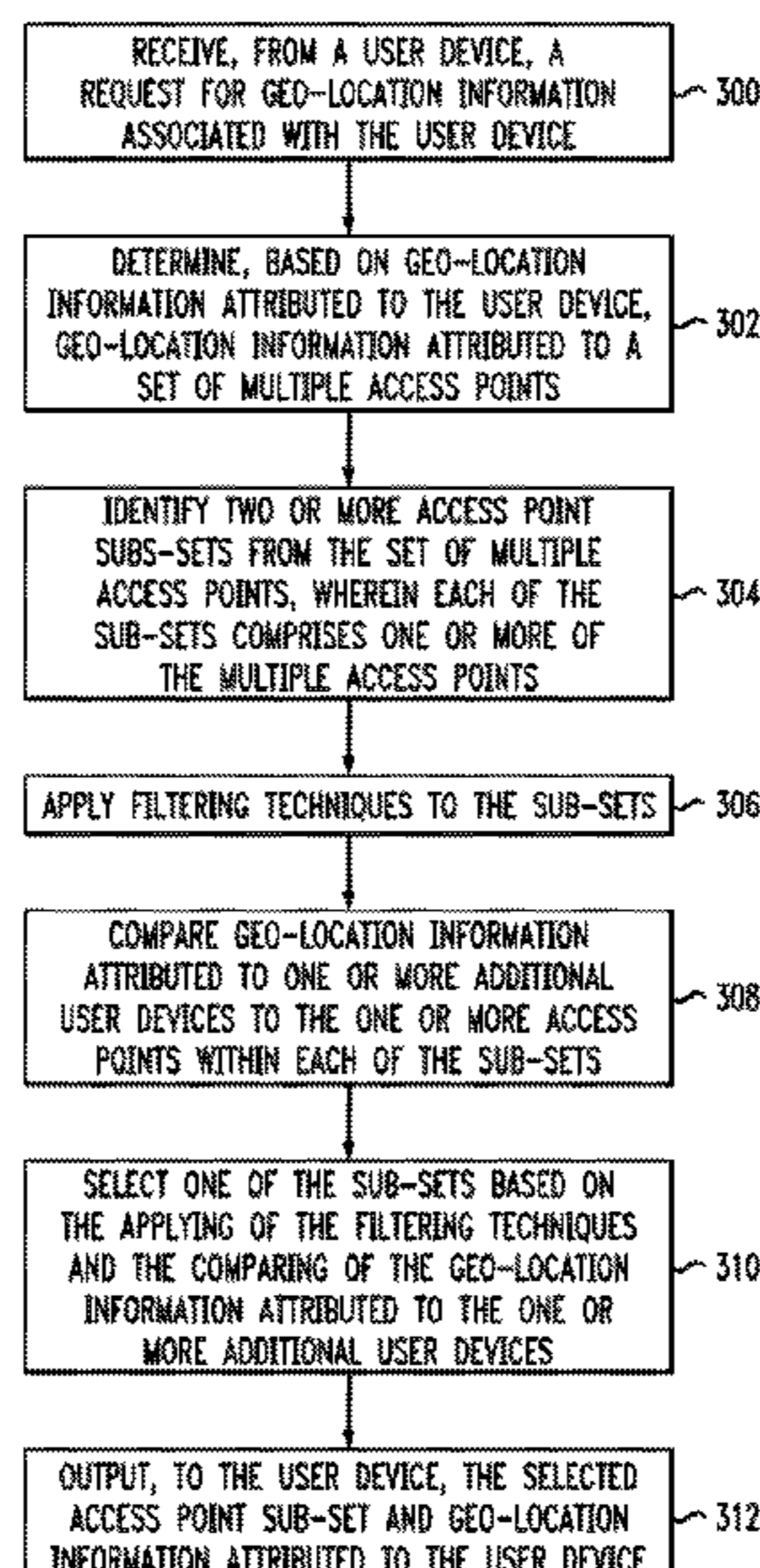
(63) Continuation of application No. 16/692,585, filed on Nov. 22, 2019, now Pat. No. 10,849,091, which is a continuation of application No. 16/363,787, filed on Mar. 25, 2019, now Pat. No. 10,616,857.

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H04W 64/00 (2009.01)
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(52) **U.S. Cl.**
CPC **H04W 64/00** (2013.01); **H04W 4/023** (2013.01); **H04W 64/003** (2013.01)

20 Claims, 3 Drawing Sheets



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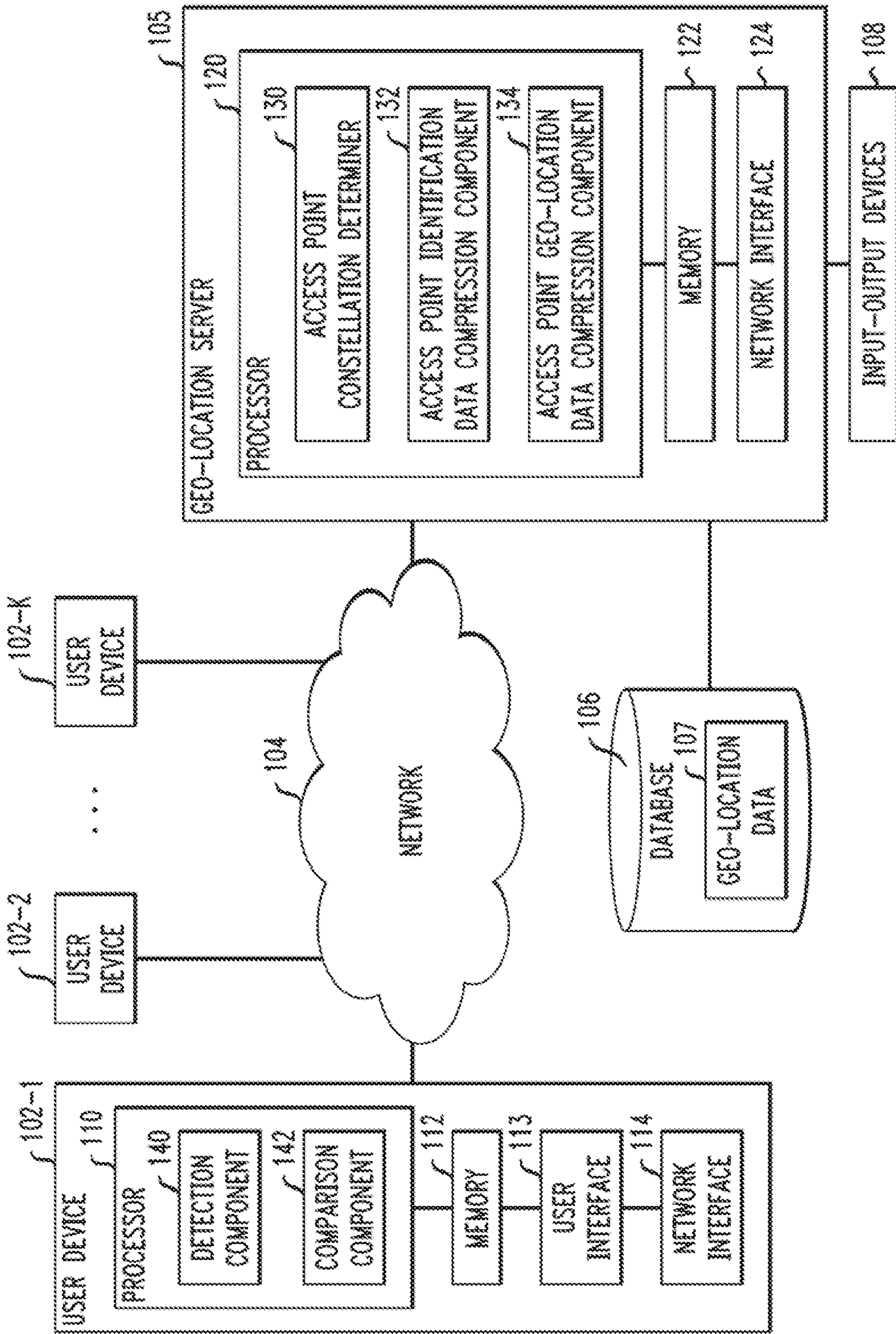
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FIG. 1
100



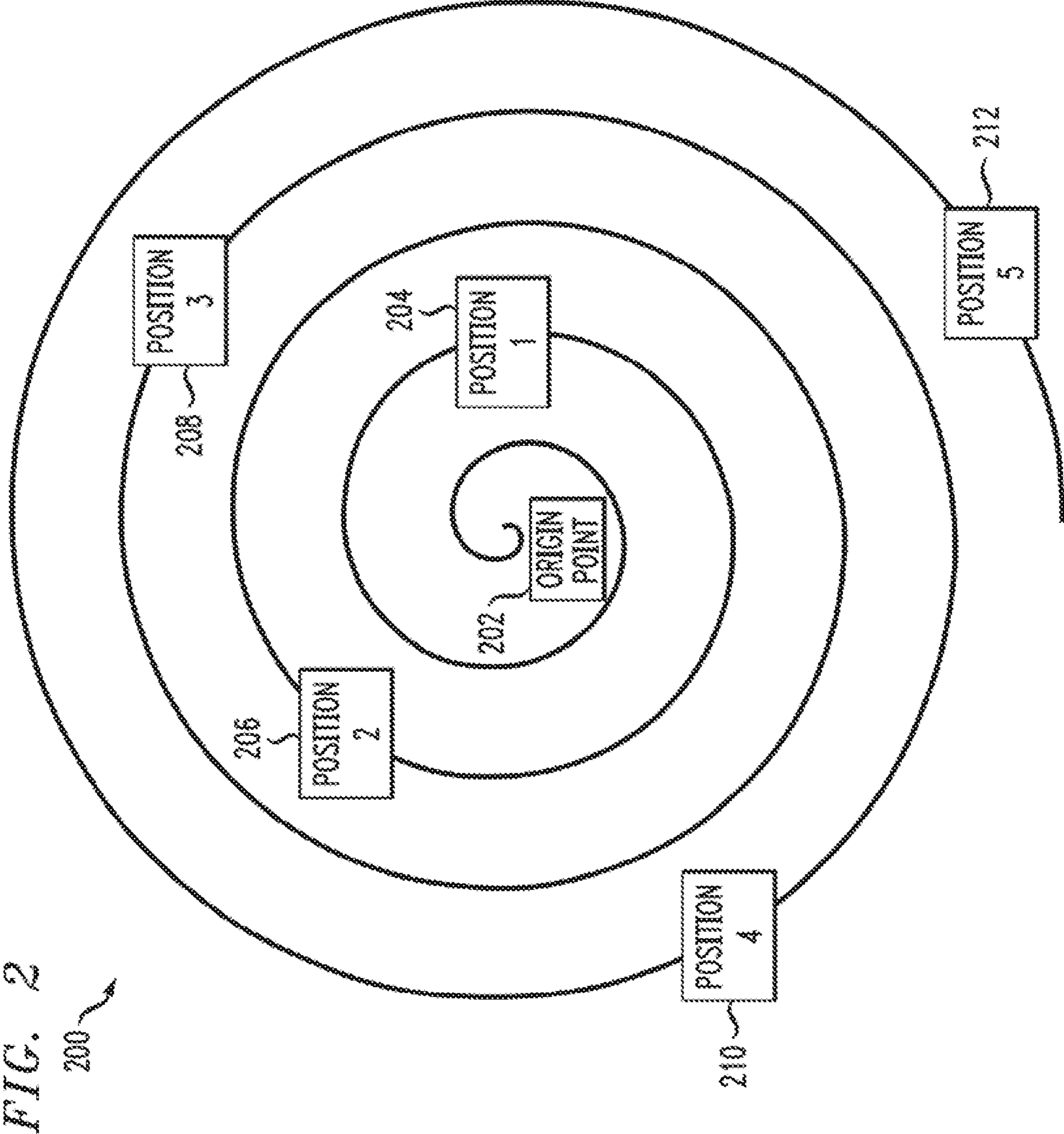
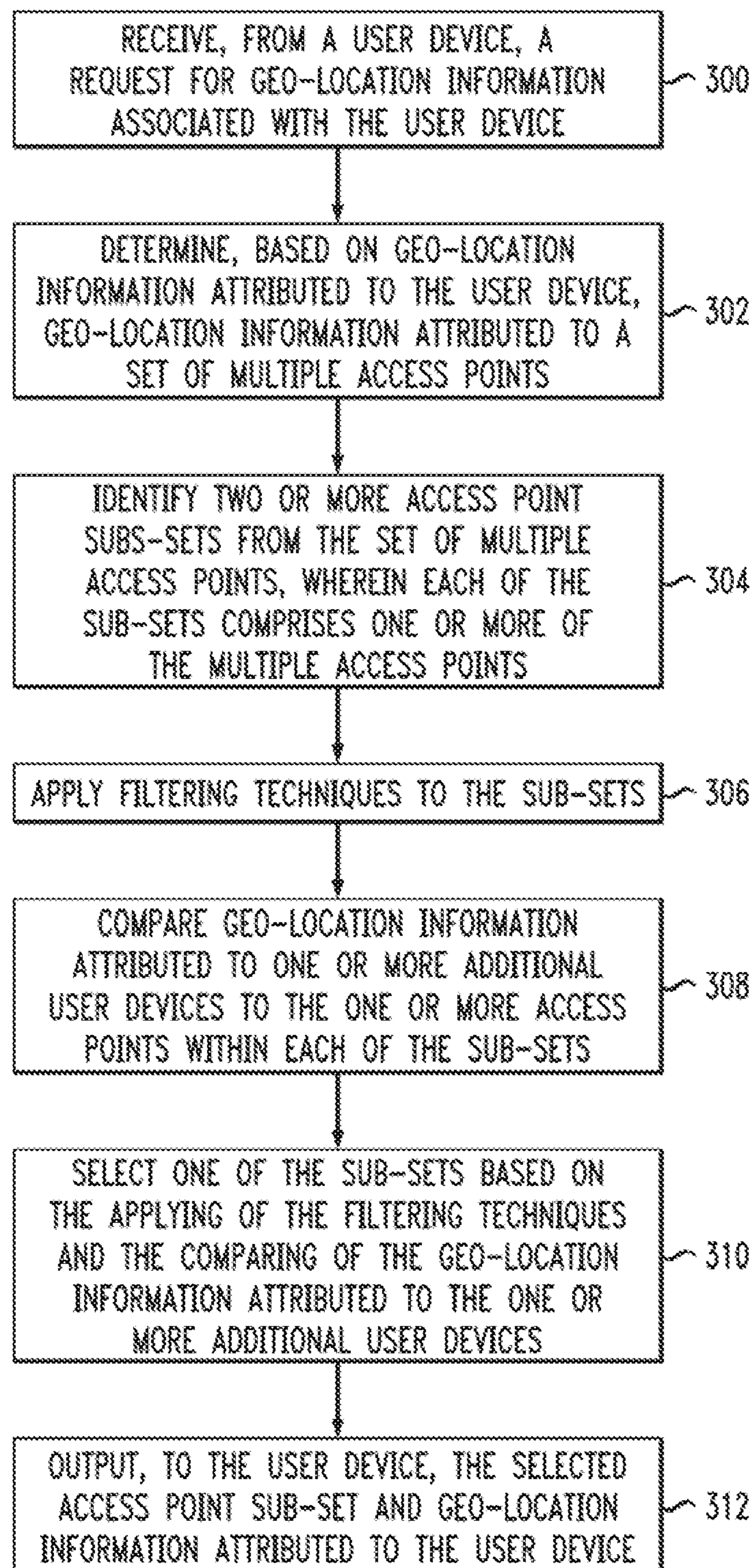


FIG. 2
200

FIG. 3



1

**DETERMINING A SET OF ACCESS POINTS
IN RESPONSE TO A GEO-LOCATION
REQUEST**

CROSS-REFERENCE TO RELATED
APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 16/692,585, filed Nov. 22, 2019, which is a continuation of U.S. patent application Ser. No. 16/363,787, filed Mar. 25, 2019, which claims priority to U.S. Provisional Application Ser. No. 62/648,159, filed Mar. 26, 2018, all of which are incorporated by reference herein. Additionally, the present application is related to U.S. patent application Ser. No. 16/363,827, entitled “Data Compression Techniques” and filed Mar. 25, 2019, and U.S. patent application Ser. No. 16/363,832, entitled “Local Determination of Geo-Location Data by User Devices” and filed Mar. 25, 2019, both of which are incorporated by reference herein.

FIELD

The field relates generally to information technology, and more particularly to data processing and transmission.

BACKGROUND

Geo-location information, with respect to users and devices, is increasingly sought-after in multiple technological settings and environments. One example mechanism for determining geo-location information includes access point geo-location techniques. Conventional access point geo-location approaches commonly include utilizing a server-maintained database of access points (for example, hardware devices such as Wi-Fi routers). Typically, a user device that is requesting its geo-location, will scan and/or monitor a surrounding area in an attempt to detect one or more access points, the identities of which the user device will transmit to the server in conjunction with the geo-location request. The above-noted identities can take the form of unique serial numbers associated with the access points (for example, media access control (MAC) addresses), which can be read by other devices (such as the user device in question). The server will commonly then compare the provided information in the request to the information stored in its database (which typically includes latitude and longitude values associated with each of the access points). Based on this comparison, the server will generally respond to the user device with an estimated geo-location of the user device, wherein the estimation is made relative to the particular access points provided by the user device in conjunction with the request.

However, such a response is commonly large in terms of data to be transmitted, typically including a full longitude value, a full latitude value, and a confidence interval. Moreover, each time that the user device seeks to update or determine its geo-location, the user device must submit a new request to the server, and the above-described request-response transmission sequence must be carried out. Accordingly (and disadvantageously), each such request-response transmission sequence requires time on the network by/for the user device to carry out the sending of the request (and receiving of the response). Also, each such request-response transmission sequence requires power consumption by the user device, depleting battery capacity in a

2

non-trivial manner. Further, there are commonly insignificant data costs associated with sending each request and receiving each response.

Accordingly, a need exists for access point geo-location techniques that reduce network costs, power costs, and data costs for requesting devices.

SUMMARY

Illustrative embodiments of the disclosure provide access point determination techniques and uses thereof. An exemplary computer-implemented method includes determining, based at least in part on geo-location information comprising a set of at least two coordinates attributed to at least one device, geo-location information attributed to a set of multiple access points, wherein an access point comprises a networking hardware device having identifiable geo-location properties. The method also includes identifying two or more access point sub-sets from the set of multiple access points, wherein each of the two or more access point sub-sets comprises one or more of the multiple access points, and comparing geo-location information attributed to one or more additional devices to the one or more access points within each of the two or more access point sub-sets. Additionally, the method also includes outputting, to the at least one device as at least part of a response to a request for geo-location information comprising a set of at least two coordinates and based at least in part on the comparing, information pertaining to at least one of the two or more access point sub-sets and the geo-location information attributed to the at least one device.

Illustrative embodiments can provide significant advantages relative to conventional access point geo-location approaches. For example, challenges associated with latency and costs are overcome through the determination of optimal access point constellations based at least in part of characteristics and properties of each of multiple access points within a given proximity of a requesting device.

These and other illustrative embodiments described herein include, without limitation, methods, apparatus, networks, systems and processor-readable storage media.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a network configured for access point geo-location compression in an example embodiment;

FIG. 2 is a diagram illustrating a spiral data structure utilized in an example embodiment; and

FIG. 3 is a flow diagram of a process for determining a set of access points in response to a geo-location request in an illustrative embodiment.

DETAILED DESCRIPTION

As detailed herein, one or more embodiments include access point geo-location (occasionally referred to herein simply as “location”) data compression techniques and uses thereof. As used herein, an access point (which can also be referred to as a wireless access point) refers to a networking hardware device which facilitates a separate device (such as, for example, a Wi-Fi device) to connect to a particular network, or a networking hardware device which may be uniquely identified and whose geo-spatial properties are likely to be known or inferred by the server, even if this networking hardware device does not facilitate any separate device to connect to a particular network (for example, a

beacon). As noted herein, one example of an access point can include a Wi-Fi router, stationary ZigBee devices, cellular data towers, machine-to-machine (M2M) networking equipment, LTE-CATM towers, narrowband-Internet of Things (NB-IOT), etc.

Example and/or illustrative embodiments will be described herein with reference to exemplary networks and associated computers, servers, network devices or other types of processing devices. It is to be appreciated, however, that the invention is not restricted to use with the particular illustrative network and device configurations shown. By way of example, the term “network” as used herein is intended to be broadly construed, so as to encompass, for example, any system comprising multiple networked processing devices.

FIG. 1 shows a network 100 configured in accordance with an example embodiment. The network 100 includes a plurality of user devices 102-1, 102-2, . . . 102-K, collectively referred to herein as user device(s) 102 (and also occasionally referred to herein as “requesting device” or simply as “device”). The user devices 102 are coupled to a network 104, where the network 104 in such an embodiment is assumed to represent a sub-network or other related portion of the larger network 100. Accordingly, elements 100 and 104 are both referred to herein as examples of “networks,” but element 104 is assumed to be a component of element 100 in the context of the FIG. 1 embodiment. Also coupled to the network 104 is geo-location server 105 (also occasionally referred to herein simply as “server”).

The user devices 102 can include, for example, location data tracking hardware devices, as well as mobile telephones or smart phones, laptop computers, tablet computers, desktop computers or other types of computing devices. The user devices 102, as illustrated in FIG. 1, can connect (wirelessly or via a hard-wired connection) to the geo-location server 105 via network 104. Accordingly, an example embodiment such as depicted in FIG. 1 includes a location data tracking hardware device (102) wirelessly connected to geo-location server 105 via network 104.

In the example embodiment illustrated in FIG. 1, the user device 102 includes a processor 110 coupled to a memory 112, a user interface 113, and a network interface 114.

The processor 110 can include, for example, a microprocessor, a microcontroller, an application-specific integrated circuit, a field-programmable gate array or other type of processing circuitry, as well as portions or combinations of such circuitry elements.

The memory 112 can include, for example, random access memory (RAM), read-only memory (ROM) or other types of memory, in any combination. The memory 112 and other memories disclosed herein can also be viewed as examples of processor-readable storage media, which can store executable computer program code and/or other types of software programs.

Examples of such processor-readable storage media can include, by way merely of example and not limitation, a storage device such as a storage disk, a storage array or an integrated circuit containing memory, as well as a wide variety of other types of computer program products. The term “processor-readable storage media” as used herein should be understood to exclude transitory, propagating signals.

The user interface 113 can be implemented, for example, to control communication between the user device 102 and the geo-location server 105, as well as to display information to a user. For example, in one or more embodiments, the user interface 113 can display information to a user of the device

102 by way of displaying graphical information of varying size based on the distance between the user device 102 and one or more other user devices in the same group (that is, devices paired with the user device of the user in question).

5 By way of further example, in at least one example, a dot or circle (that is representative of a second user device) displayed via the user interface 113 can increase in size (on the user interface 113) as the second user device moves closer to the user device in question. Similarly, in such an embodiment, the dot or circle (that is representative of the second user device) displayed via the user interface 113 can decrease in size (on the user interface 113) as the second user device moves farther away from the user device in question.

The network interface 114 allows the user device 102 to communicate over the network 104 with the geo-location server 102, and can include, for example, one or more conventional transceivers.

Additionally, processor 110 can also include a detection component 140 and a comparison component 142. It is to be appreciated that this particular arrangement of modules 140 and 142 illustrated in the processor 110 of the FIG. 1 embodiment is presented by way of example only, and alternative arrangements can be used in one or more other embodiments. For example, the functionality associated with the modules 140 and 142 in other embodiments can be combined into a single module, or separated across a number of modules. By way of further example, multiple distinct processors can be used to implement different ones of the modules 140 and 142, or portions thereof.

Also, at least portions of the detection component 140 and comparison component 142 can be implemented at least in part in the form of software that is stored in memory 112 and executed by processor 110.

Further, an example process utilizing detection component 140 and comparison component 142 of the user device in network 100 is described herein in greater detail.

Additionally, the user devices 102 can be coupled to one or more additional devices such as other location data tracking hardware devices, mobile telephones or smart phones, laptop computers, tablet computers, desktop computers or other types of computing devices.

The user devices 102, in one or more embodiments, can be coupled to respective user devices associated with a particular group, company, organization or other enterprise. Numerous other operating scenarios involving a wide variety of different types and arrangements of processing devices and networks are possible, as will be appreciated by those skilled in the art.

Also, it is to be appreciated that the term “user” herein is intended to be broadly construed so as to encompass, for example, human, hardware, software or firmware entities, as well as various combinations of such entities.

Referring again to FIG. 1, in at least one embodiment, the geo-location server 105 in the FIG. 1 embodiment can be implemented using at least one processing device. Each such processing device can include at least one processor and at least one associated memory, and can implement one or more functional software modules or components for controlling certain features of the geo-location server 105.

In the example embodiment illustrated in FIG. 1, the geo-location server 105 includes a processor 120 coupled to a memory 122 and a network interface 124.

The processor 120 can include, for example, a microprocessor, a microcontroller, an application-specific integrated circuit, a field-programmable gate array or other type of processing circuitry, as well as portions or combinations of such circuitry elements.

5

The memory **122** can include, for example, RAM, ROM or other types of memory, in any combination. The memory **122** and other memories disclosed herein can also be viewed as examples of processor-readable storage media, which can store executable computer program code and/or other types of software programs.

Examples of such processor-readable storage media can include, by way merely of example and not limitation, a storage device such as a storage disk, a storage array or an integrated circuit containing memory, as well as a wide variety of other types of computer program products.

The network interface **124** allows the geo-location server **105** to communicate over the network **104** with the user devices **102**, and can include, for example, one or more conventional transceivers.

The network **104** is assumed to include a portion of a global computer network such as the Internet, although other types of networks can be part of the network **100**, including a wide area network (WAN), a local area network (LAN), a satellite network, a telephone or cable network, a cellular network, a wireless network such as a LoRa, LoRa-WAN, SigFox or other LPWAN network, a Wi-Fi, or WiMAX network, or various portions or combinations of these and other types of networks. Also, the network **100**, in one or more embodiments, can include combinations of different types of networks, each including processing devices configured to communicate using internet protocol (IP) or other related communication protocols.

The geo-location server **105** has an associated database **106** configured to store data related to location and/or positioning requests and responses. The database **106** more particularly stores geo-location data **107**, which can include geo-location data pertaining to user devices **102**, access points, etc., as well as corresponding identification data associated with such user devices, access points, etc.

In at least one embodiment, database **106** can be implemented using one or more storage systems associated with the geo-location server **105**. Such storage systems can comprise any of a variety of types of storage including network-attached storage, storage area networks, direct-attached storage and distributed direct-attached storage, as well as combinations of these and other storage types, including software-defined storage.

Also associated with the geo-location server **105** are input-output devices **108**, which can include, by way merely of example, keyboards, displays or other types of input-output devices in any combination. Such input-output devices can be used to support one or more user interfaces (UIs) to the geo-location server **105**, as well as to support communication between the geo-location server **105** and other related systems and devices not explicitly illustrated in FIG. 1.

Also pertaining to geo-location server **105**, the processor **120** can also include access point constellation determiner **130**, access point identification data compression component **132**, and access point geo-location data compression component **134**.

It is to be appreciated that this particular arrangement of modules **130**, **132** and **134** illustrated in the processor **120** of the FIG. 1 embodiment is presented by way of example only, and alternative arrangements can be used in one or more other embodiments. For example, the functionality associated with the modules **130**, **132** and **134** in other embodiments can be combined into a single module, or separated across a number of modules. By way of further example,

6

multiple distinct processors can be used to implement different ones of the modules **130**, **132** and **134**, or portions thereof.

Also, at least portions of the access point constellation determiner **130**, access point identification data compression component **132**, and access point geo-location data compression component **134** can be implemented at least in part in the form of software that is stored in memory **122** and executed by processor **120**.

Further, an example process utilizing access point constellation determiner **130**, access point identification data compression component **132**, and access point geo-location data compression component **134** of the geo-location server **105** in network **100** is described herein in greater detail.

It is to be understood that the particular set of elements shown in FIG. 1 for geo-location data compression and transmission involving user devices **102** of network **100** is depicted by way of illustrative example only, and in one or more other embodiments, additional or alternative elements may be used.

By way merely of example, in one or more other embodiments, the geo-location server **105** can be eliminated and associated elements such as access point constellation determiner **130**, access point identification data compression component **132**, and access point geo-location data compression component **134** can be implemented elsewhere in network **100**.

At least one embodiment includes determining access point geo-location data, compressing access point geo-location data, and transmitting compressed access point geo-location data (optionally in conjunction with geo-location data pertaining to the requesting device) to a requesting device (such as user device **102**), thereby enabling the requesting device to carry out subsequent geo-location determinations using the provided compressed data.

In one or more embodiments, if a server (such as geo-location server **105**) is aware or has determined the geo-location of one or more access points, the server can ascertain geo-location information for one or more additional proximate access points. As such, if the server can return to a requesting device (for example, a device—such as user device **102**—requesting its own geo-location position from the server) multiple of these additional access points along with the device's position in space, the server can empower the requesting device to carry out its own geo-location/positional fix whenever the device wishes (so long as the requesting device is within a given proximity of the provided access points). Additionally, in such an embodiment, the requesting device would not need to communicate with the cloud to carry out the subsequent geo-location/positional fix determinations.

Further, the quality of the constellation of access points provided to the requesting device (by the server) can provide considerable value to the process of determining (locally) a positional fix of the requesting device. As used herein, a “constellation” refers to a particular grouping of one or more access points, with respect to the shape, density and clustering of the points therein. Additionally, the above-noted “value” can include increased accuracy, wherein the better the constellation returned by the server (for example, the more evenly spaced the access points whose data are returned to the requesting device), the better the requesting device will subsequently be able to accurately determine its position. As should be appreciated, in one or more embodiments, the quality of a constellation can depend on multiple variables beyond and in addition to access point density.

Multiple additional considerations and/or variables can be utilized in qualifying and/or comparing constellations.

In one or more embodiments, a server can examine and/or detect multiple access points (for example, all possible access points within a given proximity and/or radius) and perform one or more filtering functions on the detected access points. Such filtering functions can include, for example, filtering based on the (likely) quality of the access points (which can include, for instance, the age of the access points (are they likely to still exist?), the strength of the access points, etc.). Additionally, such filtering functions can also include, for example, filtering based on the quality of the particular and/or possible constellations (that is, the particular combinations of access points to be potentially provided to the requesting device). By way of further example, a server can iterate through all possible sets (constellations) of access points and select the most optimal set (constellation) of access points in terms of selecting the constellation that requires the least number of access points (and thus will allow the smallest data-sized response) that is likely to allow the requesting device to generate sufficiently accurate positional fixes.

Further, in accordance with one or more embodiments, the server can be aware of and/or can determine the geo-location of the requesting device. Also, because at least one embodiment can include primarily targeting pedestrian ambulation, the server need not necessarily return to the requesting device (in response to a geo-location request) a Gaussian distribution of access points (within a given radius of the user device). For example, if the server detects that there are many access points, and if the server has an understanding of and/or has learned historical vectors pertaining to pedestrians ambulating within the region/area in question, the server can determine a likelihood that users (and, correspondingly, their user devices) commonly move in certain directions and/or towards (or away from) certain locations (relevant to the requesting device's location/position). Based on such determinations, the server can additionally infer (without local or satellite information) that there exists one or more boundary conditions (for example, a wall, a body of water, etc.) within the relevant area surrounding the requesting device's location/position. In such an embodiment, the server will therefore not provide to the user any access points corresponding to and/or associated with the one or more inferred boundary conditions (because it is unlikely that the user will travel or be able to travel to the locations associated with those access points). Additionally, historical information pertaining to user movement can be learned by the server over time and/or over multiple iterations of geo-location requests and responses in connection with one or more user devices.

Assuming infinite memory on a requesting device, it would be optimal for the requesting device to have a complete and/or maximal set of access points to utilize for subsequent (local) geo-location determinations. However, because of limited memory, time-on-air considerations, data cost considerations, power considerations, etc., such an optimal outcome is not plausible, and as such, sub-sets of access points can be selected by the server and provided to the requesting device in response to an initial geo-location request.

Accordingly, in one or more embodiments, the server examines multiple possible constellation configurations, and ultimately selects one or more of the constellations to send to the requesting device in response to a geo-location request. In such an embodiment, the server can determine or be informed of which (if any) user devices are associated

with the requesting device during a given usage session. For example, a group of friends skiing on a mountain (or attending a concert, hiking on a trail, attending a festival, etc.) can link their user devices together and associate as a group to the server.

Additionally, in at least one embodiment, the server can be configured to incorporate the concept of an intention to return, whereby users (with their corresponding devices) inherently seek to return to a similar point of origin, to a location common to other users in a particular group, etc. Also, in one or more embodiments, the server has learned and/or is configured to learn the last-known location of each of the user devices in an established group of devices. Also, in at least one embodiment, the devices that constitute a group can be configured to associate with each other and to indicate to the server that each of the devices is a member of the group. Accordingly, in such an embodiment, the server, in determining which constellation of access points to provide to a requesting device, can consider and potentially favor access points proximate to the other devices in the requesting device's group, access points proximate to a likely path of movement (or vector) associated with other devices in the requesting device's group, etc.

Also, in one or more embodiments, the server can be configured to retain (and store) information regarding which device has received (from the server) information pertaining to which access points. Accordingly, if a subsequent response from the server is requested by a user device, the server can avoid sending duplicate access point information to that device based on the above-noted stored information.

In connection with selecting one or more constellations to send to a requesting device in response to a geo-location request, one or more embodiments include sending to the requesting device information identifying and/or describing the corresponding access points and geo-location coordinates via a reduced response set. Specifically, as further described below, such an embodiment can include compressing the MAC address attributed to each access point, compressing the latitude-longitude values attributed to each access point by converting such values to polar coordinates, and converting the polar coordinates to a position on a spiral data structure.

Accordingly, one or more embodiments include compressing the MAC address associated with each access point by taking a limited hash thereof. As would be appreciated by one skilled in the art, the MAC address of an access point is sufficiently unique to differentiate that access point from all other access points. That said, in one or more embodiments, a requesting device may only need to differentiate the access points within a locally-defined area. In such an embodiment, the server can provide, to the requesting device, a reduced hash of the identifying feature (such as, for example, the MAC address).

Further, at least one embodiment includes iterating through all possible combinations of appropriate and/or acceptable constellations within a given set of access points to identify the access points that have dissimilar hashes of MAC addresses. By way merely of example, assume that MAC addresses for a given set of four access points contain four-digit codes as follows: 4095, 3095, 2094, and 1012. Further, in this example, assume that the server is attempting to select three of these access points to form a constellation to send to a requesting device. Consequently, in one or more embodiments, the server can select the access points corresponding with codes 2094 and 1012, and one of the access points corresponding with codes 4095 and 3095. Because 4095 and 3095 end in the same two digits, one of those codes

can be selected in combination with codes **2094** and **1012**, and the three selected codes can be further hashed to two-digit codes **95**, **94** and **12**. Subsequently, these further-reduced hashes can be sent to the requesting device (thereby reducing the size of the data being transferred). In other words, in the above-noted example, of the four possible access points considered, the three selected codes can be uniquely identified by only their two trailing digits. In such an embodiment, the parameters of the heuristic chosen by the server are also sent to the requesting device, in order that the requesting device is able to use the reduced hashes to identify those access points which the server delineated in its response.

Accordingly, in an example embodiment, such as detailed above via the noted example, the complete set of appropriate and/or acceptable constellations can be iterated through (by the server) in order to determine and identify the minimum hash size to uniquely identify each corresponding access point in the constellation(s).

Additionally, latitude and longitude values can be sent with each MAC address in responding to a user device's request for a geo-location determination. As such, in one or more embodiments, rather than specifying Cartesian coordinates on an axis, polar coordinates can be implemented, and can function, for example, as follows. Given origin point (0, 0), consider a vector that is x magnitude out and 70 degrees relative to the origin point. Accordingly, at least one embodiment includes determining a polar coordinate by calculating, from a given origin point, an angle going outwards, and a magnitude value (such as, for instance, a distance from the origin point). For example, using the location of the requesting device as the origin point (and true north as 0 degrees), a polar coordinate for a given access point could be determined/represented as 270 degrees and five feet left of the origin point.

By way of illustration, consider the following example embodiment, wherein the server, in response to an initial geo-location request from a requesting device, provides only a first location (the location of the requesting device) as an absolute position (for example, in the form of a latitude-longitude pair). The location of each access point (of the selected constellation) can then be provided by the server to the requesting device as a position relative to the initial/absolute position of the requesting device. For example, the access point locations can be provided as a multi-dimensional array of access point hashes, polar coordinate angles and polar coordinate vector magnitudes.

By way merely of illustration, consider a square (square A) having sides that are each exactly 100 feet in length. Further, assume that the requesting device is positioned in the center of the square, and an access point is positioned on each of the four corners of the square. The requesting device observes the four access points and sends identification information pertaining to the four access points to the server. Consider, also, that there is another square (square B) that encompasses square A, the sides of square B are each 200 feet in length, and the center of square A and square B are the same point. There are also access points on all four corners of Square B, but the requesting device cannot see any of the access points of square B. The server determines which of the above-noted eight access points should be returned to the requesting device in conjunction with a geo-location request. Triangulation techniques, using sine, cosine and related functions, can be used to determine the angle and distance from one point to another. By way of example, a simplified version of the server's response, using general polar coordinates (that is, not a spiral data structure)

could contain the following array: {A1, 45, 70.7}, {A2, 135, 70.7}, {A3, 225, 70.7}, {A4, 305, 70.7}, {B1, 45, 141}, {B2, 135, 141}, {B3, 225, 141}, {B4, 305, 141}.

FIG. 2 is a diagram illustrating a spiral data structure **200** utilized in an example embodiment. As illustrated in FIG. 2, at least one embodiment implements and utilizes a single dimension spiral data structure for considering and/or representing geo-location data. In such an embodiment, the spiral data structure **200** is configured to have a known and predictably increasing radius, upon which an array of points is positioned, such as origin point **202**, Position1 **204**, Position2 **206**, Position3 **208**, Position4 **210** and Position5 **212**. Additionally, in such an embodiment, the distance between each of the points (that is, the density of the points on the spiral data structure) increases in a known and exponential manner. Accordingly, in such an embodiment, geo-location, as a polar vector, can be defined on a single axis, and the precision and accuracy of the geo-location determination can be scaled depending upon the underlying geometric assumptions of the spiral structure. Additionally, in such an embodiment, the user devices (and server) can be configured to interpret such spiral data structures.

Consequently, one number (the numerical position on the spiral data structure) can be associated with a compressed MAC address to represent a given access point. To convert a latitude/longitude value (that is, a coordinate to encode) into a single-number spiral position, one or more techniques can be implemented. By way merely of example, one or more embodiments include the following steps (carried out by the server). First, the server iterates through the array of points on the spiral, determines their absolute position in space (as can be known from their relative position to a known origin point), and stores these values in a table. Then, the server performs a distance calculation between the coordinate to encode each entry in the table. Additionally, these distance values are sorted (for example, from smallest to largest). The table entry that corresponds to the smallest distance between its spiral point and the value to encode provides the closest approximation of its position. The server then associates this access point entry in its response with the array index of this corresponding (most closely approximate) position.

As such, in lieu of sending, to a requesting device for each of potentially multiple access points, a combination of (i) a full MAC address (for example, 00-14-22-01-23-47), (ii) a full longitude value (for example, 37° 41'26"N 97° 20'0"W), and (iii) a full latitude value (for example, 37° 41'26"N 97° 20'0"W), at least one embodiment includes sending, to the requesting device for each access point, (a) the minimum uniquely-identifying hash size (for example, a reduced hash such as "95" in the above-detailed example) to uniquely identify each corresponding access point in the constellation (s) and (b) a single numerical value (such as "5," indicating point Position5 on the spiral data structure) that represents the latitude and longitude values of the access point relative to the location of the requesting user device or some other known and/or pre-determined location. In one or more embodiments, the spiral data structure can be oriented relative to the current location of the requesting user device, can be oriented relative to due north, etc.

By way merely of illustration of an example embodiment, consider the following. A requesting device requests an initial geo-location determination (of the requesting device) from a server. In the first response packet from the server, an absolute position is defined for the requesting device and/or one or more access points. In one or more subsequent responses, geo-location positioning for the requesting device

and/or one or more access points can be defined as a spiral data structure relative to the originally-defined absolute position from the first response packet.

Such an example embodiment can increase the precision of access points proximate to the user device's current position. As such, as the requesting device moves farther away from the originally-defined absolute position, the server can provide more diffuse positional possibilities.

Also, in one or more embodiments, a response generated by the server can include a table of access points, and the table can include, for each access point, a compressed hash and a number that indicates a position on an array (for example, a spiral data structure having a geometry that is known both to the server and to the requesting device). Using such a response, as detailed further below, the requesting device can subsequently carry out and execute its own geo-location requests.

In at least one embodiment, a requesting device can convert a geo-location response (as detailed herein) generated/provided by the server into a format that the device can then use for local calculations. For example, the requesting device, based on the response from the server, can identify the geo-location of certain access points. Accordingly, in one or more embodiments, the requesting device can compare the information provided by the server (compressed MAC addresses and corresponding spiral data structure position numbers, for example) to information pertaining to access points that the requesting device can actually detect at that moment (via, for example, a Wi-Fi scan).

By way merely of example, assume that the response from the server included information attributed to Access Point 1, Access Point 2, Access Point 3, and Access Point 4. Further assume that the requesting device subsequently seeks to re-determine its geo-location, and the device scans the surrounding area and determines that Access Point 1 and Access Point 2 are strongly detected while Access Point 3 is no longer detected. Accordingly, the requesting device can infer and/or determine its own geo-location positioning based on this detected information relative to Access Point 1, Access Point 2, and Access Point 3. By way of further example, assume that the requesting device subsequently detects Access Point 4 (wherein the device had previously been unable to detect Access Point 4), providing additional information by which the requesting device can infer and/or determine its geo-location positioning.

Further, in at least one embodiment, the requesting device can be configured to carry out and execute such geo-location requests locally as many times as the device (or the user of the device) wants or is capable of computing. In accordance with such an embodiment, the energy costs to the device associated with receiving data (listening and/or detecting) are lower than the energy costs to the device associated with transmitting data. As such, the local geo-location determinations require significantly less data costs and network on-air time than the initial request-response communication sequence between the requesting device and the server (and as in conventional approaches).

FIG. 3 is a flow diagram of a process for determining a set of access points in response to a geo-location request in an illustrative embodiment. It is to be understood that this particular process is only an example, and additional or alternative processes can be carried out in other embodiments.

In this embodiment, the process includes steps 300 through 312. These steps are assumed to be performed, for example, by the processor 120 (of geo-location server 105) utilizing module 130.

Step 300 includes receiving, from a user device, a request for geo-location information associated with the user device. As used herein, geo-location information associated with a user device can include, for example, one or more constellations of access points and geo-location information attributed to such access points. Additionally, as used herein, geo-location attributed to a user device and/or access point can include, for example, MAC address information and longitude-latitude information describing the geo-location of that user device and/or access point. Further, in at least one embodiment, a user device can make a geo-location request (for example, to a server) via manual input of the user interface of the device, automatically via a sensed connection and/or a temporal schedule with a server, etc.

Step 302 includes determining, based at least in part on geo-location information attributed to the user device, geo-location information attributed to a set of multiple access points, wherein an access point comprises a networking hardware device having identifiable geo-location properties. Determining geo-location information attributed to a set of multiple access points can include detecting all access points within a given proximity of the user device. Additionally, at least one embodiment includes determining the geo-location information attributed to the user device.

Step 304 includes identifying two or more access point sub-sets from the set of multiple access points, wherein each of the two or more access point sub-sets comprises one or more of the multiple access points. Each of the two or more access point sub-sets is identified with respect to shape of the sub-set, density of the sub-set, a clustering pattern of the one or more access points contained therein, etc.

Step 306 includes applying one or more filtering techniques to the two or more access point sub-sets. The one or more filtering techniques can include filtering based on age of the access points within the two or more access point sub-sets, based on strength of the access points within the two or more access point sub-sets, etc.

Step 308 includes comparing geo-location information attributed to one or more additional user devices to the one or more access points within each of the two or more access point sub-sets. In at least one embodiment, the one or more additional user devices participate in a designated group with the user device. Such an embodiment can include identifying the one or more additional user devices participating in the designated group with the user device, as well as learning a last-known geo-location of each of the user devices in the designated group.

Step 310 includes selecting at least one of the two or more access point sub-sets based at least in part on (i) the applying of the one or more filtering techniques and (ii) the comparing of the geo-location information attributed to the one or more additional user devices. At least one embodiment includes selecting the at least one selected access point sub-set by selecting based at least in part on the last-known geo-location of each of the user devices in the designated group. Also, in one or more embodiments, the at least one selected access point sub-set includes the at least one access point sub-set containing the least number of access points. Additionally, in at least one embodiment, the at least one selected access point sub-set includes the at least one access point sub-set containing dissimilar hashes of media access control addresses among the access points contained therein.

Step 312 includes outputting, to the user device as at least part of a response to the request for geo-location information, the at least one selected access point sub-set and geo-location information attributed to the user device. Outputting can include outputting, to the user device, (i) media

access control address information attributed to each access point contained within the at least one selected access point sub-set, and (ii) latitude-longitude values attributed to each access point contained within the at least one selected access point sub-set.

The techniques depicted in FIG. 3 can also include inferring one or more boundary conditions within a given proximity of the user device based at least in part on historical data pertaining to users moving within the given proximity. In such an embodiment, selecting the at least one selected access point sub-set includes selecting based at least in part on avoiding conflict with the one or more inferred boundary conditions. Further, the techniques depicted in FIG. 3 can additionally include storing an indication that the user device has been provided with the at least one selected access point sub-set.

Other techniques can be used in association with one or more embodiments of the disclosure. Accordingly, the particular processing operations and other network functionality described in conjunction with the flow diagram of FIG. 3 and the above-noted techniques are presented by way of illustrative example only, and should not be construed as limiting the scope of the disclosure in any way. For example, the ordering of the process steps may be varied in one or more other embodiments, or certain steps may be performed concurrently with one another rather than serially. Also, the process steps or subsets thereof may be repeated periodically in conjunction with respective distinct instances of geo-location data requests with respect to different users and/or user devices.

The above-described example embodiments provide significant advantages relative to conventional approaches. For example, one or more embodiments include compressing access point geo-location via hash reduction as well as converting polar coordinates to a one-dimensional spiral data structure of known/established geometric parameters. Additionally, one or more embodiments include enabling a requesting device to carry out geo-location determinations locally using an initial compressed access point geo-location data packet.

It is to be appreciated that the foregoing advantages are illustrative of advantages provided in certain embodiments, and need not be present in other embodiments.

Additionally, the networks disclosed herein can be implemented, for example, using one or more processing platforms. Such a processing platform can include, by way of example, at least one processing device comprising a processor coupled to a memory.

In one or more embodiments, portions of a network as disclosed herein can illustratively include cloud infrastructure. The cloud infrastructure, in at least one such embodiment, can include a plurality of containers implemented using container host devices, and/or can include container-based virtualization infrastructure configured to implement Docker containers or other types of Linux containers.

The cloud infrastructure can additionally or alternatively include other types of virtualization infrastructure such as virtual machines implemented using a hypervisor. Additionally, the underlying physical machines include one or more distributed processing platforms that include one or more storage systems.

Such cloud infrastructure as described above can, by way of example, represent at least a portion of one processing platform. Another example of such a processing platform can include, as similarly detailed above in connection with FIG. 1, a plurality of processing devices which communicate with one another over a network. As yet another processing

platform example, portions of a given processing platform in one or more embodiments can include converged infrastructure.

The particular processing platforms described above are presented by way of example only, and a given network such as network 100 can include additional or alternative processing platforms, as well as numerous distinct processing platforms in any combination, with each such platform comprising one or more computers, servers, storage devices and/or other processing devices.

Further, in accordance with one or more embodiments, processing devices and other network components can communicate with one another using a variety of different communication protocols and associated communication media.

It should again be emphasized that the embodiments of the disclosure described herein are presented for purposes of illustration only. Many variations may be made in the particular arrangements shown. Moreover, the assumptions made herein in the context of describing one or more illustrative embodiments should not be construed as limitations or requirements of the disclosure, and need not apply in one or more other embodiments. Numerous other alternative embodiments within the scope of the appended claims will be readily apparent to those skilled in the art.

What is claimed is:

1. A computer-implemented method comprising:

determining, based at least in part on geo-location information comprising a set of at least two coordinates attributed to at least one device, geo-location information attributed to a set of multiple access points, wherein an access point comprises a networking hardware device having identifiable geo-location properties;

identifying two or more access point sub-sets from the set of multiple access points, wherein each of the two or more access point sub-sets comprises one or more of the multiple access points;

comparing geo-location information attributed to one or more additional devices to the one or more access points within each of the two or more access point sub-sets; and

outputting, to the at least one device as at least part of a response to a request for geo-location information comprising a set of at least two coordinates and based at least in part on said comparing, information pertaining to at least one of the two or more access point sub-sets and the geo-location information attributed to the at least one device;

wherein the method is carried out by at least one computing device.

2. The computer-implemented method of claim 1, comprising:

applying one or more filtering techniques to the two or more access point sub-sets.

3. The computer-implemented method of claim 2, wherein the one or more filtering techniques comprises filtering based on age of the access points within the two or more access point sub-sets.

4. The computer-implemented method of claim 2, wherein the one or more filtering techniques comprises filtering based on signal strength of the access points within the two or more access point sub-sets, wherein signal strength comprises geolocation information derived from at least one previously known geolocation.

5. The computer-implemented method of claim 1, comprising:

15

determining the geo-location information attributed to the at least one device.

6. The computer-implemented method of claim 1, wherein said determining geo-location information attributed to a set of multiple access points comprises detecting all access points within a given proximity of the at least one device.

7. The computer-implemented method of claim 1, wherein each of the two or more access point sub-sets is identified with respect to at least one of (i) shape of the sub-set and (ii) density of the sub-set.

8. The computer-implemented method of claim 1, wherein each of the two or more access point sub-sets is identified with respect to a clustering pattern of the one or more access points contained therein.

9. The computer-implemented method of claim 1, wherein the one or more additional devices participate in a designated group with the at least one device.

10. The computer-implemented method of claim 9, comprising:

identifying the one or more additional devices participating in the designated group with the at least one device; and

learning a last-known geo-location of each of the devices in the designated group.

11. The computer-implemented method of claim 1, comprising:

inferring one or more boundary conditions within a given proximity of the at least one device based at least in part on historical data pertaining to users moving within the given proximity.

12. The computer-implemented method of claim 1, wherein said outputting comprises outputting, to the at least one device, (i) media access control address information attributed to each access point contained within the at least one of the two or more access point sub-sets, and (ii) latitude-longitude values attributed to each access point contained within the at least one of the two or more access point sub-sets.

13. The computer-implemented method of claim 1, comprising:

storing an indication that the at least one device has been provided with the at least one of the two or more access point sub-sets.

14. A non-transitory processor-readable storage medium having stored therein program code of one or more software programs, wherein the program code when executed by at least one processing device causes the at least one processing device:

to determine, based at least in part on geo-location information comprising a set of at least two coordinates attributed to at least one device, geo-location information attributed to a set of multiple access points, wherein an access point comprises a networking hardware device having identifiable geo-location properties;

to identify two or more access point sub-sets from the set of multiple access points, wherein each of the two or more access point sub-sets comprises one or more of the multiple access points;

16

to compare geo-location information attributed to one or more additional devices to the one or more access points within each of the two or more access point sub-sets; and

to output, to the at least one device as at least part of a response to a request for geo-location information comprising a set of at least two coordinates and based at least in part on said comparing, information pertaining to at least one of the two or more access point sub-sets and the geo-location information attributed to the at least one device.

15. The non-transitory processor-readable storage medium of claim 14, wherein the program code when executed by the at least one processing device causes the at least one processing device:

to apply one or more filtering techniques to the two or more access point sub-sets.

16. The non-transitory processor-readable storage medium of claim 14, wherein each of the two or more access point sub-sets is identified with respect to at least one of (i) shape of the sub-set and (ii) density of the sub-set.

17. The non-transitory processor-readable storage medium of claim 14, wherein each of the two or more access point sub-sets is identified with respect to a clustering pattern of the one or more access points contained therein.

18. An apparatus comprising:

at least one processing device comprising a processor coupled to a memory;

the at least one processing device being configured:

to determine, based at least in part on geo-location information comprising a set of at least two coordinates attributed to at least one device, geo-location information attributed to a set of multiple access points, wherein an access point comprises a networking hardware device having identifiable geo-location properties;

to identify two or more access point sub-sets from the set of multiple access points, wherein each of the two or more access point sub-sets comprises one or more of the multiple access points;

to compare geo-location information attributed to one or more additional devices to the one or more access points within each of the two or more access point sub-sets; and

to output, to the at least one device as at least part of a response to a request for geo-location information comprising a set of at least two coordinates and based at least in part on said comparing, information pertaining to at least one of the two or more access point sub-sets and the geo-location information attributed to the at least one device.

19. The apparatus of claim 18, wherein the at least one processing device is further configured:

to apply one or more filtering techniques to the two or more access point sub-sets.

20. The apparatus of claim 18, wherein each of the two or more access point sub-sets is identified with respect to at least one of (i) shape of the sub-set and (ii) density of the sub-set.